Our Reference LLT-259-B **PATENT**

CONTROL AND MOTOR ARRANGEMENT FOR USE IN MODEL TRAIN

Field of the Invention

The present invention relates to model railroads. More particularly, the present invention relates to control and motor arrangements for use in model trains.

Background

Model train systems have been in existence for many years. In a typical model train system, the model train engine is an electrical engine that receives power from a voltage that is applied to the tracks and picked up by the train motor. A transformer is used to apply the power to the tracks. The transformer controls both the amplitude and polarity of the voltage, thereby controlling the speed and direction of the train. In HO systems, the voltage is a DC voltage. In Lionel® systems, the voltage is an AC voltage transformed from the 60 Hz line voltage provided by a standard wall socket.

Some conventional types of model train systems are susceptible to performance degradation related to track irregularities. For example, uneven portions of the track can cause the model train to intermittently lose contact with the track, causing power to be inadvertently removed from the train. Unwanted stopping can result. In addition, upward and downward grades in the track can cause the model train to travel slower or faster than desired due to the effects of gravity. Moreover, certain model train systems fail to adequately simulate the effects of inertia. For example, in some systems, when power is removed from the train, the train stops moving immediately. By contrast, real world trains do not stop immediately when brakes are applied. Accordingly, in some model train systems, play-realism is reduced by these sudden stops.

Summary of the Invention

According to one embodiment, the present invention is directed to a control and motor arrangement for use in a model train. The control and motor arrangement includes a motor, configured and arranged to generate a locomotive force for propelling the model train. A control arrangement is coupled to receive speed information from the motor and is configured and arranged to provide a control signal to the motor for controlling the speed of the motor.

Another embodiment of the present invention is directed to a control and motor arrangement for use in a model train. The control and motor arrangement includes a motor, configured and arranged to generate a locomotive force for propelling the model train. A control arrangement is configured and arranged to provide a speed control signal to the motor generated as a function of speed information received from the motor. The control arrangement is further configured and arranged to provide the information received from the motor to a sound control arrangement.

Still another embodiment of the present invention is directed to a control and motor arrangement for use in a model train. A motor is configured and arranged to generate a locomotive force for propelling the model train. A power arrangement coupled to a model railroad track used by the model train is configured and arranged to supply power to the control and motor arrangement. A command control interface, which is a radio control interface in the preferred embodiment, receives commands from a command control unit, which is a radio control unit in the preferred embodiment. A process control arrangement, responsive to the command control interface, is configured and arranged to control a rotational speed of the motor in response to rotational speed information received from the motor. A motor control arrangement is responsive to the process control arrangement and is coupled to receive power from the power arrangement. The motor control arrangement generates a magnetic field for driving the motor. A sound information arrangement receives rotational speed and positional information from the motor and provides the rotational speed and positional information to a sound control arrangement for simulating railroad sounds.

The above summary of the present invention is not intended to describe each illustrated embodiment or every implementation of the present invention. The

figures and the detailed description that follow more particularly exemplify these embodiments.

Brief Description of the Drawings

These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description and upon reference to the drawings, in which:

FIGURE 1 illustrates an example control and motor arrangement installed in a model train, according to an embodiment of the present invention;

FIGURE 2 is a profile view, in section, of an example control and motor arrangement for use in a model train, according to another embodiment of the present invention;

FIGURE 3 is a plan view of an example control and motor arrangement for use in a model train, according to another embodiment of the present invention;

FIGURE 4 is a block diagram illustrating an example control arrangement forming part of a control and motor arrangement for use in a model train, according to yet another embodiment of the present invention;

FIGURES 5A and 5B are portions of a schematic diagram depicting an example circuit arrangement for implementing the control arrangement illustrated in FIGURE 4; and

FIGURES 6, 7A - 7D, and 8 are portions of a schematic diagram depicting another example circuit arrangement for implementing the control arrangement illustrated in FIGURE 4.

The invention is amenable to various modifications and alternative forms. Specifics thereof have been shown by way of example in the drawings and will be described in detail. It should be understood, however, that the intention is not to limit the invention to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the invention as defined by the appended claims.

Detailed Description

The present invention is believed to be applicable to a variety of model railroad systems. The invention has been found to be particularly advantageous in environments in which it is desirable to operate a model train under a variety of rail conditions. An appreciation of various aspects of the invention can be gained through a discussion of various application examples operating in such environments.

According to one embodiment of the present invention, a control arrangement receives information from a model train motor regarding the current speed and position of the motor. This information is used to maintain a constant operating speed of the motor over a variety of rail conditions, including, for example, changes in grade. The motor realizes higher torque and efficiency. In addition, jerking and other adverse effects commonly associated with low speed operation of the motor are reduced. Furthermore, an inertial effect can be simulated by continuing to operate the motor for a duration after a main power source is disconnected from the motor. In another particular embodiment of the present invention, two or more motors are disposed on opposite surfaces of a control arrangement. Using multiple motors increases the locomotive power available to the model train.

In still another particular embodiment of the present invention, the motor speed and position information, as well as information relating to power consumption by the motor, is provided to a sound control system. The sound control system uses this information in selecting sounds to generate, enhancing the realism of the model railroad system and, for many hobbyists, the level of enjoyment.

Referring now to the drawings, FIGURE 1 depicts a control and motor arrangement installed in a model train **100**. The model train **100** includes a platform **102**, under which a wheeled carriage **104** is mounted to support the model train **100** on a track (not shown). A control and motor arrangement **106** is mounted on a top surface of the platform **102**. The control and motor arrangement **106** includes a control arrangement **108**, which is coupled to control the amount of power supplied to a motor **110**. This motor **110** can be implemented using any of a variety of motor types, including, for example, a DC can-type, ODYSSEY™-type, or PULLMOR™ type motor, commercially available from Lionel LLC of Chesterfield, Michigan. Those skilled in the

art will recognize that other motor types can be used in the alternative, and that the preceding examples are provided by way of illustration and not limitation. The control arrangement receives from the motor **110** speed information relating to the current rotational speed of the motor **110** and uses this information to adjust the amount of power applied to the motor **110** using a closed feedback loop.

In addition, the control arrangement **108** optionally further receives from the motor **110** information relating to, for example, the position within the rotational cycle of the motor **110** and/or the amount of power consumed by the motor **110**. This information is used in deciding how much power to apply to the motor **110**. For example, slow rotation of the motor **110** can indicate that the model train **100** is traveling along an upward slope. To compensate for this slope, the control arrangement **108** supplies additional power to the motor **110**. By compensating for variations along the model railroad track, the control arrangement **108** maintains the motor **110** at a constant rotational speed, if the user so desires.

The control arrangement **108** can also be used to produce other effects that enhance the sense of realism a user enjoys when operating the model train **100**. For example, a real train is significantly affected by inertia. This effect can be observed both when the train starts and stops moving. When a real train starts moving, it does not accelerate to full speed immediately. On the contrary, the train accelerates slowly due to inertia. This effect can be simulated in the model train **100** by applying power to the motor **110** gradually, even when the user commands the model train **100** to assume full speed immediately. Just as a real train typically does not accelerate to full speed instantaneously, it does not, under normal operating conditions, immediately halt when power is removed. Rather, inertia causes the train to continue to move for some time before coming to a halt. This gradual stopping can be simulated in the model train **100** by supplying power to the motor **110** from an alternate power source, such as a battery (not shown), for a time after the primary power source is disconnected from the motor **110**.

The information provided by the motor **110** to the control arrangement **108** is optionally also provided to other systems in the model train **100**, such as a sound control system. The sound control system can use this information in generating realistic

sound effects. For example, if the sound control system receives an indication that the motor **110** is drawing a relatively large amount of power without a correspondingly large increase in speed, the sound control system can fairly conclude that the motor **110** has to work harder to maintain the model train **100** at a constant speed. The sound control system can then select or generate a sound effect that simulates the sound of a train engine straining to drive a train up a hill.

FIGURE 2 illustrates an example control and motor arrangement **200** for use in a model train. A circular base **202** forms a support structure, upon which a rotor **204** is mounted. The rotor **204** rotates about an axis **206** when the control and motor arrangement **200** is energized, driving a motor shaft **208** into rotation about the axis **206**. The motor shaft **208** is supported by a bearing structure comprising spaced apart bearings **210**.

When the motor is energized, a plurality of windings **212** wound around respective bobbins **214** interact to generate an electromagnetic field within laminar core components **216** and the base **202**. This field interacts with magnets **218** mounted on the rotor **204**, causing the rotor **204** to rotate about the axis **206**. The motor shaft **208** is thus driven into rotation. FIGURE 3 illustrates in plan view one example of a configuration of windings **212** and core components **216**. In the particular example illustrated in FIGURE 3, a stator winding assembly **300** consists of nine core components **216** and associated bobbins **214** and windings **212**. As the motor shaft **208** rotates, a plurality of rotation sensors, one of which is depicted at reference numeral **220**, detect the change in position of the rotor **204**. These rotation sensors **220** can be implemented, for example, using conventional Hall effect detectors. The Hall effect detectors sense voltages produced by changes in the electromagnetic field set up by the windings **212**. In a particular embodiment of the present invention, a plurality of Hall effect detectors, e.g., three, are evenly disposed around the circumference of the control and motor arrangement **200**. With this configuration of rotation sensors **220**, the voltage produced in each rotation sensor **220** varies as a function of the position of the rotor **204** with respect to the base **202**. A control circuit arrangement **222** is connected to the motor. The control circuit arrangement **222** receives input from the Hall effect detectors and determines, from the voltages produced in each detector, the position of the rotor **204**

in the rotation cycle. In addition, the control circuit arrangement **222** monitors changes in the voltages produced in the detector to infer how quickly the rotor position changes, i.e., the rotational speed of the rotor **204**.

The control circuit arrangement **222** uses this speed and positional information to determine whether, and to what extent, to alter the amount of power supplied to the motor. For example, if the control circuit arrangement **222** determines that the rotor **204** is rotating slowly for the amount of power supplied to it, the control circuit arrangement **222** can command that more power be supplied to the motor. According to a particular embodiment of the present invention, the speed and positional information is also provided to a sound control arrangement (not shown) to facilitate the generation of sound effects with enhanced realism.

FIGURE 4 illustrates in block diagram form an example control circuit arrangement **400** forming part of a control and motor arrangement, according to another embodiment of the present invention. A power arrangement **402** supplies power to the system. The power arrangement **402** receives power from the model railroad track and also includes a battery circuit to supply power in certain situations, such as when the model train travels over an uneven portion of the track and makes only intermittent contact with the track. Power is supplied to a motor control arrangement **404**, which creates the rotating magnetic field that drives the motor. The power arrangement **402** also provides power to other components of the system, such as a sound control arrangement **414**.

It is understood that the present invention may be used with model toy trains which operate with either command control interfaces, or trains which are conventionally controlled through variations in the track voltage (e.g. use of a D.C. offset to sound a model toy train horn) to control the train. The conventional train would require modification to include speed control arrangement **222** including sensors **220** connected thereto as shown in FIGURE 7.

A command control interface **406** provides an interface between the control arrangement **400** and a command control unit operated by the user. The radio controller unit is used to access various functions, such as speed control, sound effects, and the like. A process control arrangement **408** receives commands from the command

control interface **406** and maintains the speed of the motor at the desired level. For example, if the user commands the model train to run at 40 mph, the process control arrangement **408** maintains the speed at 40 mph, compensating for such factors as upward or downward grades or curves in the track. The process control arrangement **408** also detects faults in the system, such as short circuits. In the event of a short circuit, a short circuit protection arrangement **410** disengages power from the motor when the current flow exceeds a predefined threshold.

The process control arrangement **408** accesses a memory **412**, which stores certain user-defined information. For example, the user can define a relationship between the rotational speed of the motor and a corresponding speed of the model train. In a particular embodiment of the present invention, the memory **412** is implemented using a nonvolatile memory to facilitate storage of the user-defined information after power is removed from the system.

The present invention may use a detected track voltage in implementing a speed control arrangement for conventionally controlled model trains. Track voltage is detected between rail 1 and rail 3 as shown in FIGURE 7 and 8. Referring first to FIGURE 8, full-wave rectifier bridge **604** provides a DC voltage (RAW DC) which is proportional to the AC track voltage present on rail 1 and rail 3. RAW DC is supplied to software programmed microcontroller U101 (FIGURE 7A) via jumper JP201 (FIGURE 8) , header 610 (FIGURE 7C), resistors R101, R102 (FIGURE 7A), and capacitor C105 (FIGURE 7A). In this way microcontroller U101 can determine the level fo AC track voltage present on rail 1 and rail 3. Those of ordinary skill in the art will recognize that many circuit variation are possible for determining the level of AC track voltage.

Control arrangement **408** may apply a defined percentage of the track voltage to motor **110**. The difference between the track voltage and the voltage applied to motor **110** is not used and is effectively kept in reserve. When the speed of motor **110** decreases, such as when the model toy train encounters increased loading, control circuit arrangement **222** detects a reduction in speed and increases the amount of track voltage sent to motor **110**. For example, at a comparatively low speed, roughly 60% of the available track voltage may be applied to motor **110**, with 40% of available track voltage being kept in reserve. At increased loading of motor **110**, its rotational speed will decrease. The decrease in speed will be sensed by sensors **220** and process control

arrangement **222** will operate to apply an increased voltage to motor **110** thereby reducing the amount kept in reserve and keeping motor **110** at its selected speed.

For conventional model toy trains outfitted with arrangement **222** and sensors **220**, speed may additionally be set as follows. A user may adjust the track voltage to a desired speed and once at that point simultaneously press the horn and raise the track voltage thereby establishing the fixed speed for the speed control. It is understood that other combinations of signals may also be programmed to set speed. The user may then increase the track voltage to establish a reserve to be used to maintain the speed of motor **110** during increased loading as above described.

A sound information arrangement **414** detects certain operating conditions of the model train and transmits information relating to these conditions to a sound control arrangement (not shown). For example, the sound information arrangement **414** is configured to detect whether the train is traversing a grade and, if so, whether the grade is upward or downward. The sound control arrangement processes this information and selects appropriate sound effects to enhance the sense of realism. For example, if the model train is moving uphill, the process control arrangement **408** senses that more power is required to maintain a constant speed. The process control arrangement **408** thus increases the power supply to the motor. In addition, the sound information arrangement **414** informs the sound control arrangement that more power has been supplied to the motor. The sound control arrangement then selects a sound effect consistent with additional power, such as increased simulated diesel engine noise.

FIGURES 5A and 5B illustrate an example circuit arrangement implementing the control arrangement **400** of FIGURE 4, according to a particular embodiment of the present invention. Primary power is supplied to the circuit from a connection **502** to a rail power supply. A rectifier arrangement **504** converts the AC voltage between the rails to a DC voltage for use by the train. In addition, a connection **506** to a battery serves as an alternate power source when, for example, contact with the rails is interrupted. With the battery serving as a secondary power source, the train maintains operation in the event of such interruptions. A battery circuit **508** conveys power from the battery to the control arrangement **400**. A motor controller **510** is responsible for generating the rotating magnetic field that drives the train motor. In the

specific embodiment illustrated in FIGURES 5A and 5B, this magnetic field is generated in three alternating zones. These three zones correspond to three AND gates **512**, each of which receives as input a pulse width modulation signal PWM and a control signal OUTi. The control signals OUT are provided by a process controller **514**, the operation of which is discussed in detail below. When the control signal OUT and the pulse width modulation signal PWM are both active for a particular AND gate **512**, power is supplied to a corresponding portion of the motor through a CMOS arrangement **516** and a motor connection **518**. As each portion of the motor receives power in turn, a magnetic field is generated in that portion of the motor. A short circuit protection circuit **520** provides a path to ground in the event of a short circuit. The control signals OUT are generated by the process controller **514** so as to cause the field to rotate around the motor.

To generate the control signals OUT, the process controller **514** monitors the rotational speed of the motor using an input **522** coupled to, for example, a Hall effect sensor. Monitoring the speed of the motor enables the process controller **514** to maintain a constant speed, if desired, over a variety of track conditions. For example, if the process controller **514** senses that the motor is rotating slowly relative to the amount of power supplied to it, it can infer that the train is traveling uphill or over otherwise challenging terrain and apply more power to the motor. Similarly, if the process controller **514** detects that the motor is rotating quickly relative to the amount of power supplied to it, the process controller **514** can decrease the amount of power supplied to the motor to maintain a constant speed. In this manner, the process controller **514** uses speed control closed loop feedback to maintain the motor at a constant operating speed, regardless of track conditions, when desired.

In addition to the speed of the motor, the process controller **514** optionally receives other inputs that determine the proper amount of power to supply to the motor. For instance, as illustrated in FIGURES 5A and 5B, the process controller **514** receives information from a user-operated remote control through a radio control interface **524**. This information includes, for example, the desired simulated speed of the train, directional control information, and commands to effect simulation of various sound effects.

The determination of how much power to supply to the motor depends not only on the input from the remote control and the current speed of the motor, but also on certain user-defined information, such as a mapping between a real-world train speed to be simulated and an actual speed of the model train. In the embodiment illustrated in FIGURES 5A and 5B, this user-defined information is stored in a non-volatile memory **526**, such as a ROM or an EPROM.

According to a particular embodiment of the present invention, the process controller **514** outputs speed information to a sound control circuit (not shown) using an output interface **528**. The sound control circuit uses the speed information to determine how to generate or select an appropriate, realistic sound effect. For example, a horn can be programmed to sound relatively quietly when the train is running slowly, but forcefully as the train picks up speed.

FIGURES 6 - 8 depict another example circuit arrangement implementing the control arrangement **400** of FIGURE 4, according to still another embodiment of the present invention. In the circuit arrangement illustrated in FIGURES 6 - 8, primary power is supplied to the circuit from a connection **602**, illustrated on FIGURE 8, to a rail power supply. A full-wave rectifier bridge **604** converts the AC voltage between the rails to a DC voltage for use by the train. In addition, a connection **606** to a battery serves as an alternate power source when contact with the rails is interrupted. The train can thus maintain operation even when such interruptions occur. A battery circuit **608** conveys power from the battery to the control arrangement **400** through a connection **610**. To drive the train motor, the control arrangement generates a rotating field. In the specific embodiment illustrated in FIGURES 6 - 8, the magnetic field is generated in three alternating zones, each corresponding to an AND gate **612**. Each AND gate **612** receives as input a pulse width modulation signal PWM and a control signal LOW 1, LOW 2, or LOW 3. These signals are generated by a microprocessor **614**, the operation of which is discussed in further detail below. When the control signal LOW _n (where n is 1, 2, or 3) and the pulse width modulation signal PWM are both active for a particular AND gate **612**, power is supplied to a corresponding portion of the motor using a respective CMOS arrangement **616**. A motor connector **618** provides power to a respective zone of the motor. On FIGURE 6, the zones are depicted at reference numerals **620**. As each zone

of the motor receives power in turn, a magnetic field is generated in that zone. A short circuit protection circuit, depicted at reference numeral **622** on FIGURE 8, provides a path to ground in the event of a short circuit. The microprocessor **614** generates the control signals LOW_n so as to cause the field to rotate around the motor.

To generate the control signals LOW_n, the microprocessor **614** monitors the rotational speed of the motor using interfaces (**624** of FIGURE 6) to Hall effect sensors (not shown). A connector **626** connects the interfaces **624** to the microprocessor **614**. By monitoring the motor speed, the microprocessor **614** can use closed loop feedback to adjust the amount of power supplied to the motor in response to changes in motor speed. Thus, the microprocessor **614** can maintain a constant speed over a variety of track conditions, such as changes in grade.

The microprocessor **614** can also receive other inputs to influence the amount of power to be supplied to the motor. For example, a connection **628** to a control interface enables the hobbyist to provide additional information to the microprocessor **614** using a user-operated radio controller. This information includes, for example, the desired simulated speed of the train, directional control information, and commands to effect simulation of various sound effects. User-defined information, such as a mapping between a real-world train speed to be simulated and an actual speed of the model train, also affects the determination of the amount of power to supply to the motor. In the embodiment illustrated in FIGURES 6 - 8, this user-defined information is stored in a non-volatile memory **630**.

According to a particular embodiment of the present invention, the microprocessor **614** outputs speed information to a sound control circuit (not shown) using an output interface **632**. The sound control circuit uses the speed information to determine how to generate or select an appropriate, realistic sound effect. For example, a horn can be programmed to sound relatively quietly when the train is moving slowly, but forcefully as the train speed increases. It should be noted that, in the embodiment depicted in FIGURES 6 - 8, either resistor 8106 or resistor 8107 of the output interface **632** is installed. In one embodiment, resistor **8106** is installed to allow direct pin control of audio gain control. As an alternative, resistor **8107** can be installed instead, allowing gating of the PWM signal.

The various embodiments described above are provided by way of illustration only and should not be construed to limit the invention. Those skilled in the art will readily recognize various modifications and changes that can be made to these embodiments without strictly following the example embodiments and applications illustrated and described herein, and without departing from the true spirit and scope of the present invention, which is set forth in the following claims.